CCC 2018

Proceedings of the Creative Construction Conference (2018)
Edited by: Miroslaw J. Skibniewski & Miklos Hajdu
DOI 10.3311/CCC2018-140

Creative Construction Conference 2018, CCC 2018, 30 June - 3 July 2018, Ljubljana, Slovenia

Virtual Reality Applications in Architecture: Bill of Quantities & Virtual Reality

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Abstract

As time goes on and building practices change, procedures that at one point seemed indispensable can fall by the wayside. One such example is the bill of quantities (B/Q). Research into recent literature attributes this decline in use to a multitude of reasons such as its complexity and potentially drawn-out time to produce, non-traditional procurement systems growing in popularity and the challenge of using its information in a construction schedule. With these issues in mind, a combined process of BIM, Virtual Reality and including the client in the design process has been proposed as a potential solution.

Following a literature review and precedent study, an experiment was carried out using this new process to simulate a client's design decisions on window and interior furnishings specifically. Their choices made using Virtual Reality automatically updated a B/Q Revit Schedule and allowed the client to have a firm grasp on the project costs. Not only did this process give the client more confidence in a pleasing final outcome, but the technology ensured an up-to-date, accurate and easily understood B/Q. Here lies great potential savings in cost, time and gives the B/Q a newfound importance in future construction processes.

Keywords: Virtual Reality; Bill of Quantities; BIM; Revit

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1. Introduction

A B/Q is a document introduced in Great Britain after the Industrial Revolution in the 19th century. At that time, it was put in place in order for tradesmen to pay their workers and as a fee for clients. Presently, it has evolved to specify the qualitative and quantitative aspects of every element in a proposed project. Essentially forming a record of all the items used in construction [1]. It is commonly used for estimating costs as part of the traditional procurement process and is an important part of a tender document. However, literature suggests that their use is declining due to a variety of reasons such as its complicated and time-consuming preparation, an increase of non-traditional procurement systems and difficulty incorporating its information into a real life construction schedule [2 & 3]. In relation to a client, it attempts to supply comprehensive cost information yet as a project progresses, it is common for costs to increase and the B/Q left without updating [1]. At times, this can leave a client feeling uninformed on how exactly their money is being used and the overall financial status of the project.

This study will counter this by investigating the use of BIM and Virtual Reality as a means of including the client in design decisions and creating an improved bill of quantities process. Focussing on aesthetic choices like the size and position of windows, and interior furnishings will illustrate VR's ability to improve the design process and better satisfy the client's desires. Moreover, as the client makes these choices they will have direct access to an updated B/Q and fully understand the costs involved. Using this technology aims to modernize the B/Q process and convert a potentially complex document into an accessible and interactive user experience.

2. Bill of Quantities

As pointed out previously the Bill of Quantities has been an important estimating tool used for centuries, during this time there have been many technological advancements that have improved the efficiency the B/Q and of construction estimation the introduction of CAD/CAE systems in the 1950 is one example [4]. As the construction industry once again moves forward technologically with the widespread adoption of BIM and VR systems the; use, functionality and efficiency of the B/Q should be revisited. The B/Q is still widely used particularly in traditionally procured schemes, where it not only provides cost estimates for clients but also forms part of the tender document, used by speculative contractors to price, programme and bid for a potential contract [1]. In recent years, however, the amount of traditionally procured construction contracts has been declining in favour of more modern systems such as; design and build or management contracting, which often forgo the need of a B/Q. These procurement systems have several benefits over Traditional procurement such as condensing the tender and design phase, while also reducing client financial risk. The tender is condensed in modern procurement methods, in part by removing the need to prepare a B/Q which is often a lengthy and onerous process [5]. Modern procurement methods can also give a client a degree of cost certainty which is not possible with traditional procurement [5] this is usually achieved - such as in Design and Build – by giving the contractor more control over the design of a project, while also creating more liability for the contractor when a project's costs overrun. Modern procurement methods are not suitable for all projects however, particularly in smaller one-off projects where control over the design is more important. The RIBA plan of work 2013 overview points out that the traditional contract route remains by far the most dominant form of procurement. Therefore, the production and quality of the B/Q must continue to be refined as it is vital to the traditional procurement system.

If a B/Q is of poor quality, it can seriously undermine the validity of a tender and lead to inaccurate estimates, higher margins in bids, claims and disputes [6]. This means that a bill of B/Q is typically produced by a trained quantity surveyor who bases the document on specifications and drawings produced by the architect [2]. This highlights one of the major issues that can lead to a poor-quality B/Q; Architect's drawings. As the B/Q is directly derived from architect's schedules and drawings, the document is vulnerable to client's oversight or misunderstanding of elements presented within these schedules and drawings such as; interior finishes, carpentry and ironmongery. These oversights and misunderstandings generally need to be rectified later and are often only caught after construction has begun, which leads to rework and increased costs. This issue is described by Li and Love: "A significant number of rework in construction is caused by client last minute changes and their inability to acquire a realistic appreciation of the product from the 2-D drawings at the design stage" [7]. If a client cannot grasp a realistic appreciation of the -typically- 2-D drawings and schedules produced by architect (which is what the B/Q is based upon) prior to the tender stage, the accuracy of the B/Q is undermined even before it has been created. Therefore, the accuracy of a B/Q can be improved by helping the client understand what is actually in that document [7]. Li and Love proposed a solution for this issue, which they believe is caused by the presentation of a buildings design in 2D format. They created a 3D visualisation system that allowed clients to 'walkthrough' a design so that they could get a;

"virtually real appreciation of the interior layout and its architectural details" [7]. This allowed clients to suggest changes to the design before it was 'quantified' into a B/Q. This improved the accuracy of the B/Q as it accurately reflected the client's aspirations for the project, it also prevented any 'last-minute' client changes that could have incurred extra cost. While the 'walkthrough' provided significant benefits over the standard 2D architectural drawings, Li and Love concluded by suggesting that immersing a client in a VR environment might allow for an even more accurate reflection of a client's aspirations which would also improve the accuracy of the B/Q. This in would be possible, by giving the client an appreciation of a design similar to the way they experience buildings in real life, negating the need for them to 'acquire a realistic appreciation' of a design through 2D drawings.

3. Development Strategy

In order to create this prototype, the group broke down its development into several stages: creating the BIM model and B/Q, converting the model into VR, designing and building in VR, interactive design presentation and a precedent study. First, the BIM model. The model being used is a private housing design that was created in Revit as part of a past project. This was deemed well suited to our prototype because the typology offers a closer and more involved relationship between architect and client.. A lot of care is placed on finding the client's preferred furnishings and exact detailing to perfect their home and VR can be very useful in this situation. Moreover, each of these design decisions can greatly alter the, generally speaking, smaller budget of most residential projects therefore giving the bill of quantities a heightened importance. The window types and furnishings used in the prototype were created by researching contractor's building information and manufacturer Revit packs respectively. The information from the chosen architectural element is then automatically included into a Revit schedule which calculates pricings.

To transfer the model into VR, various methods were considered. As [8] explain, a common workflow is completing your model in Revit, converting into another separate graphing software, like 3Ds Max, and then finally load that FBX file into a gaming engine such as Unreal or Stingray. It has also been noted by the writers that during this complex and time-consuming process it is common for information to be lost. Furthermore, there is no synchronization with updated models [9] meaning if the design was updated in Revit, the whole process has to be repeated.

After comparing the different programs and methods available to the group, it was decided that the plugin Enscape would be the most effective. The chosen plugin works directly with programs like Revit in order to create real-time and fully navigable VR [10]. It only takes mere minutes to translate drawing data to VR with generally no information lost and with only a click of a button. This fully resolves the previously mentioned issues of time and complexity. In addition, in regards to the synchronisation problem mentioned above, Enscape proved itself as particularly apt. If there were any changes made to the linked Revit model, the live VR model will automatically be updated. In a client meeting, this has the potential to give clients a better understanding of the changes they desire and leaves no surprises as the project moves to construction. Enscape offers the client a true, life-like and dynamic imitation of a planned space that is much easier to understand than an abstracted 2D drawing.

The presentation is an important part of the architectural process. Presenting to a client should be clear and a smooth flowing representation of the design solution is necessary in order to gain approval and maintain the client's confidence. Using a variety of different software here is the solution. Combining Revit for modelling and Enscape for visualisation, the design team are able to make changes in real time and makes the work easy to understand for the clients. Enscape simply updates the design changes allowing you to demonstrate to the client how the project looks and how different objects sit in the space. This inspiring presentation tool offers immediate implementation into a workflow and can save time and money.

The final stage of the development strategy was to perform a precedent study on the currently available programs that the group could look to for guidance. However, it was soon clear to see that the current applications were limited in their scope. For example, the IKEA showroom demonstrates to the client what products from their catalogue look like and how they fit into a room on a VR 360 degree camera orientation, although this is not to the client's room specification or showing the price of each item [11]. Zerolight and Design Milk showrooms for Audi and Cadillac provide the clients with full customization of the vehicles and is the most detailed VR application, but again does not provide the client with the price break down of each part [12&13]. The applications all seem to provide an incomplete service that could be improved for a better client experience. VR showrooms should offer strong visuals showing what the client is buying and variations on the item in different environments, colours and sizes, while also providing the client with accurate pricing. This paper will now proceed to describe the prototype and the process of achieving this.

 DOI 10.3311/CCC2018-141

4. Prototype

During the development strategy key stages in the prototype development were identified as detailed in Chapter 3. The client will then gain a better understanding of the design and help them perceive what they require for their build. The BIM model itself was designed as a new two storey detached house which can be utilised to suit the clients requirements within the manufacturers catalogue. Within our prototype the catalogue that we based our internal furnishings on was IKEA; this allowed us to generate 3D models directly from IKEA's catalogue and then import them into Revit. There was a different process for modelling the windows; instead of a catalogue they were generated based on manufacturers specifications [14]. This meant that all BIM information needed to be obtained from the manufacturers website and developed into specific window types for use in the model [15]. We merged our Revit prototype into Enscape, which allowed us to do testing within the VR. Enscape can also be used to spectate what the VR headset user is seeing but in real tray rendering which provides the Architect with a visual input for what the client is looking at and can refer to when discussing design revision.

The prototype model was designed with rooms such as the living room, dining room and bedroom to test the development strategy by placing windows and furniture at specified positions. Both testers acted the role of the Architect and client however there were many errors before reaching this stage. The Oculus software proved to be an issue; the software was bugged and wouldn't allow VR use, however after several tries this was no longer the case and the VR was usable. Once access to the model was obtained, the movement speed of the controller needed to be adjusted as it was too fast and gave the tester motion sickness. The height of the user also needed scaled to the model. Otherwise the movement around the room was deemed sufficiently accurate and testing could commence. The testers then had access to OBS - a recording software - which then put layers on top of each other in real time and began recording results, firstly testing with the group members and then with another participant. There were many takes as the recording crashed when altering some types of furniture.

During testing we gathered data revolved around three rooms within the prototype, the living room which was focused on furniture and windows, whereas the dining room and bedroom just had the furniture. These rooms were set up with standard furniture at first to provide the feel of scale in the room. From this the client can add, remove or alter the placed furniture within the chosen room which will update and change on the custom-made B/Q schedule. All the furniture and windows within the test rooms refer to the B/Q schedule which is updated live when something is added or removed.

Figure 1 - Revit model immersed in VR

 DOI 10.3311/CCC2018-141

The living room test consisted of altering the window widths and heights to the clients requirements whilst using the VR headset and receiving live updates from the Architect. The furniture was also altered by the Architect upon the client's request. The elements within a single item of furniture that can be altered are the texture, colour, size and style. The amendments processed by the client within the VR are transferred to a custom-made B/Q schedule which can be seen in figures 2 & 3.

Window Schedule							
Type	Count	Level	Manufacturer	Width	Height	Cost	Comments
Circle Window - 600mm Diameter	1	00 Floor Level	Glass Tops	600		£70.00	
Circle Window - 900mm Diameter	1	00 Floor Level	Glass Tops	900		£80.00	
Sash Window - 900 x 1200mm	1	00 Floor Level	Glass Tops	900	1200	£1140.00	
Sash Window (Vintage) - 850x1850mm	4	00 Floor Level	Jeld Wen Windows & Doors	850	1850	£5400.00	
Sash Window (Vintage) - 1000x1850mm	6	00 Floor Level	Jeld Wen Windows & Doors	1000	1850	£9420.00	
Grand total						£16110.00	

Figure 2 - Window schedule

Furniture Schedule (Living Room)						
Room: Department	Type	Description	Manufacturer	Count	Cost	Comments
Living Room	Lampan Lamp	(B) 130 x (W) 400 x (H) 290	IKEA	2	£32.00	
Living Room	Coffee Table	(L) 550 x (W) 550 x (H) 450	IKEA	2	£50.00	
Living Room	Shelving Uint	(W) 388 x (L) 1500 x (H) 803	IKEA	1	£40.00	
Living Room	Low Lounge Table	(W) 900 x (L) 1800 x (H) 450	IKEA	1	£75.00	
Living Room	Branco TV Stand	(W) 400 x (L) 1200 x (H) 480	IKEA	1	£105.00	
Living Room	Bench Sofa	(W) 660 x (L) 1830 x (H) 800	IKEA	2	£420.00	
Living Room	Plasma TV	50"	IKEA	1	£500.00	
Grand total					£1222.00	

Figure 3 - Living room furniture schedule

The test for the dining room involved adding, removing and altering furniture from the catalogue to the model, as per client instructions as seen in figure 4. The combination with the client being immersed while the architect can live update is bridging the gap where Architects have been wanting to cross. These tests show that it is possible to cross this bridge and get more benefits from it in return with example a more accurate B/Q and the clients direct sign off for progression to the next stages. With any furnishings required as seen in figure 5 the B/Q can be flexible to illustrate more variations in case the budget is an issue for the client

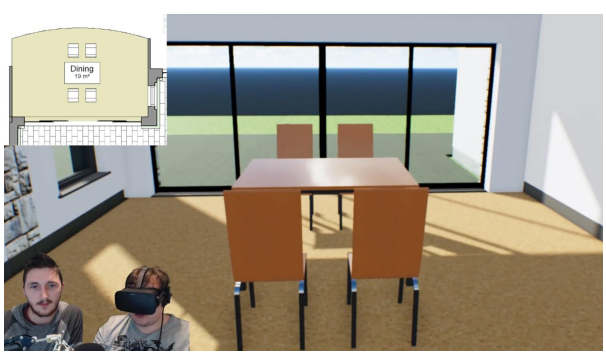

Figure 4 - The prototype tests showing changes in furniture.

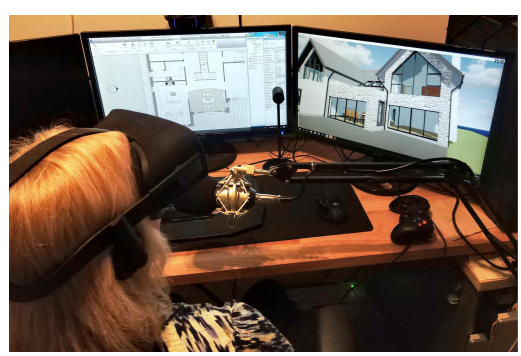

Figure 5 - The participant making changes within VR

5. Conclusion

Overall the results of this prototype had very few issues in terms of the software being used. The findings we encountered through the process included a smooth transition from BIM to VR. Overall it was easily imported from Revit into Enscape, the software we used for the prototype only required a plugin for Revit. The main issues we encountered were the setup of the Oculus Software due to the quantity of softwares used to setup the presentation -, Revit and Enscape along with the Oculus software itself. A participant for the prototype was used to try the experiment out themselves and this identified issues to be addressed. These included the height of the tester and the movement speed of the controller. The client can gain a more realistic appreciation for the design before it is priced as they can get a new perspective of the structure seeing it in VR. In a normal plan a client could get confused due to miscommunication therefore VR is the way forward for allowing the client to understand the design.

There are many improvements that can still be made to this method before it can be considered a gold-standard. Firstly, there could be a better integration strategy brought forward in terms of allowing the client to see the B/Q within the VR. This would allow the client to see the costing within the headset therefore being unable to understand the cost of each change. Right now we are able to make changes in live time however that is done solely through Revit and through the Architect. In future this could be adapted so that the client can have some or all control in terms of positioning and the Architect. Another possible development that could enhance the experience is breaking down the B/Q to a more simplistic form so the client can understand it better. In an attempt at this we broke down the schedules to windows and furniture separately and within each room instead of a full overall cost. A further improvement to this would be the update in window size costs incorporating the construction as well as the component prices.

References

[1] Rashid, R. A., Mustapa, M., & Wahid, S. N. A. (2006). Bills of Quantities-Are they still useful and relevant today. Paper presented at the International Conference on Construction Industry.

[2] Odeyinka, H., Kelly, S., & Perera, S. (2009). An evaluation of the budgetary reliability of bills of quantities in building procurement. Paper presented at the COBRA 2009: Construction and Building Research Conference of the Royal Institution of Chartered Surveyors, University of Cape Town, 10-11 September 2009.

[3] Bandi, S., Abdullah, F., & Amiruddin, R. (2014). Recapitulating the issues Concerning the Applications of the Bills of Quantities. International Journal of Built Environment and Sustainability, 1(1).

[4] Olatunji, O. A. (2011). Virtual reality and estimating practice: A software selection model for estimating. practice, 11, 13.

[5] Davis, P. R., Love, P. E., & Baccarini, D. (2009). Bills of Quantities: nemesis or nirvana? Structural Survey, 27(2), 99-108.

[6] Laryea, S. (2011). Quality of tender documents: case studies from the UK. Construction Management and Economics, 29(3), 275-286.

[7] Li, H., & Love, P. E. (1998). Visualization of building interior design to reduce rework. Paper presented at the Information Visualization, 1998. Proceedings. 1998 IEEE Conference on.

[8] Bille, R., Smith, S. P., Maund, K., & Brewer, G. (2014). Extending building information models into game engines. Paper presented at the Proceedings of the 2014 Conference on Interactive Entertainment.

[9] Du, J., Zou, Z., Shi, Y., & Zhao, D. (2018). Zero latency: Real-time synchronization of BIM data in virtual reality for collaborative decision-making. Automation in Construction, 85, 51-64.

[10] AEC Magazine/ Corke, C. (2017). Review: From Revit to VR. [online] Available at: https://www.aecmag.com/technology-mainmenu-35/1255-review-from-revit-to-vr. [Accessed 9 February 2018].

[11] Agency, D. (2018). IKEA Virtual Reality Showroom. [online] Demodern Digitalagentur. Available at: http://demodern.com/projects/ikea-vr-showroom [Accessed 2 Feb. 2018].

[12] Han, G. (2017). Cadillac Brings VR Showrooms Ever Closer to Reality - Design Milk. [online] Design Milk. Available at: https://design-milk.com/cadillac-virtual-reality/ [Accessed 2 Feb. 2018].

[13] Light, Z. (2018). ZeroLight. [online] Zerolight.com. Available at: https://zerolight.com/ [Accessed 2 Feb. 2018].

[14] Glasstops. (2015). Glasstops UK - Bespoke Glass Manufacturer - Order Online. [online] Available at: http://www.glasstops.co.uk/ [Accessed 5 Apr. 2018].

[15] Jeld-wen, (2000). Interior and Exterior Doors, Windows, Patio Doors, Stairs - JELD-WEN. [online] Available at: http://www.jeld-wen.co.uk/ [Accessed 5 Apr. 2018].